

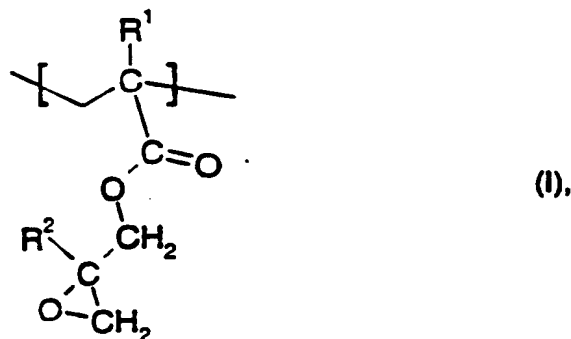
Curable composition

The invention relates to a curable composition based on acidic polyesters and on certain polyglycidyl compounds and to a powder coating composition based thereon.

JP-A-Sho 57-108166 discloses a curable composition and the use thereof as a powder coating composition, the composition comprising

- (A) from 60 to 96 parts by weight of a polyester having an acid number of from 20 to 200 mg of KOH per gram, a softening point of from 80 to 150 °C and a molecular weight (number average) of from 1000 to 10 000,
- (B) from 3 to 40 parts by weight of an acrylic polymer containing glycidyl groups and having a molecular weight (number average) of from 300 to 5000,
- (C) from 1 to 20 parts by weight of a further epoxy resin, which may be, *inter alia*, diglycidyl terephthalate or triglycidyl isocyanurate, and
- (D) an accelerator for the reaction of epoxy groups with carboxyl groups.

There are used as component (B) polymers or copolymers that contain identical or different structural repeating units of formula (I):



wherein the radicals  $R^1$  and  $R^2$  are each independently of the other a hydrogen atom or a methyl group.

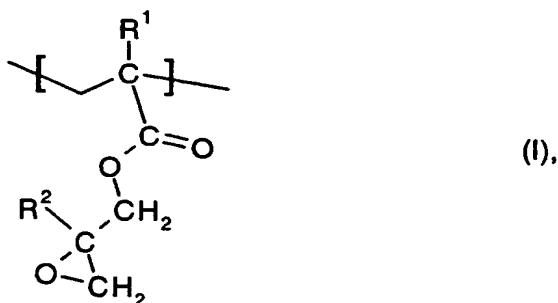
As can be seen from the above quantitative data, the said compositions contain at least approximately 2.5 % by weight of component (B), based on the total amount of components (A), (B) and (C). The flow behaviour of the compositions is generally still not satisfactory, however, and accordingly when such compositions are used in the production of powder

resin coatings there is, in particular, a risk that the known orange-peel effect will occur, that is to say, that a coating having a very uneven surface will be formed.

The present invention is based on the surprising discovery that the flow behaviour of the above-mentioned curable compositions is substantially improved but, nevertheless, cured material having excellent physical properties, especially excellent mechanical properties, is obtainable by using as component (B) of the compositions a maximum of 2 percent by weight, based on the total amount of components (A), (B) and (C), of one or more polymers or copolymers that each have an epoxy value of at least 3 equivalents per kilogram and a molecular weight (number average  $M_n$ ) of from 800 to 20 000 and that contain identical or different structural repeating units of the formula (I) already mentioned above.

The present invention accordingly relates to a curable composition comprising:

- (A) from 80 to 97.9 percent by weight, based on the total amount of components (A), (B) and (C), of a polyester component having an acid number in total of from 10 to 40 mg of KOH per gram of the component and consisting of one or more polyesters containing free carboxyl groups;
- (B) from 0.2 to 2 percent by weight, based on the total amount of components (A), (B) and (C), of a component consisting of one or more polymers or copolymers that each have an epoxy value of at least 3 equivalents per kilogram and a molecular weight (number average  $M_n$ ) of from 800 to 20 000 and that contain identical or different structural repeating units of formula (I):



wherein  $R^1$  and  $R^2$  are each independently of the other a hydrogen atom or a methyl group; and

- (C) a component consisting of one or more monomeric polyglycidyl compounds having an epoxy value of at least 3.5 equivalents per kilogram and a maximum molecular weight of 600, the amount of component (C) in percent by weight, based on the total amount

of components (A), (B) and (C), corresponding to the difference between 100 and the sum of the percentage amounts of components (A) and (B) based on the total amount of components (A), (B) and (C); and

(D) an accelerator for the reaction of epoxy groups with carboxyl groups, wherein, furthermore, component (B) constitutes from 5 to 95 percent of the total weight of components (B) and (C) and the molar ratio of glycidyl groups to carboxyl groups in the composition is from 1.3:1 to 1:1.3.

Curable compositions according to the present invention are distinguished, *inter alia*, by a very good flow behaviour and yield a cured material that has a high crosslinking density and excellent mechanical properties.

The curable compositions according to the invention are suitable, for example, as adhesives, casting resins or compression-moulding compositions, it being possible for further components that are conventional in the field of use in question to be admixed therewith, as desired.

Special preference is given to powder coating compositions that contain as curable component system the compositions according to the invention. The invention accordingly relates also to powder coating compositions based on the curable compositions according to the invention.

The polyester component (A) constitutes preferably from 85 to 96 percent by weight, especially from 88 to 95 percent by weight, of the composition according to the invention based on the total amount of components (A), (B) and (C).

The acid number of from 10 to 40 mg of KOH per gram applies to the polyester component as a whole, and therefore corresponds, when several different polyesters are used, to the average acid number of the totality of those polyesters. Preference is given to compositions according to the invention in which the polyester component (A) has an acid number in total of from 20 to 40 mg, preferably from 22 to 38 mg, of KOH per kilogram of the component.

The polyesters of component (A) are advantageously solid at room temperature (from 15 to 35°C) and have, for example, a molecular weight (number average  $M_n$ ) of from 1000 to

10 000. The ratio of Mw (weight average of the molecular weight) to Mn of those polyesters is generally from 2 to 10. There are especially suitable for the present invention, for example, free-carboxyl-group-containing polyesters having a molecular weight (weight average Mw from GPC measurement using polystyrene calibration) of from 4000 to 15 000, especially from 6500 to 11 000, and a glass transition temperature (Tg) of from 35 to 120°C, preferably from 50 to 90°C.

Polyesters such as those mentioned are described, for example, in US-A-3 397 254 and EP-A-0 600 546. Polyesters suitable for the present invention are condensation products of difunctional, trifunctional and/or polyfunctional alcohols (polyols) with dicarboxylic acids and, optionally, trifunctional and/or polyfunctional carboxylic acids, or with corresponding carboxylic acid anhydrides. The polyols used include, for example, ethylene glycol, diethylene glycol, the propylene glycols, butylene glycol, 1,3-butanediol, 1,4-butanediol, neopentanediol, isopentyl glycol, 1,6-hexanediol, glycerol, hexanetriol, trimethylolethane, trimethylolpropane, erythritol, pentaerythritol, cyclohexanediol and 1,4-dimethylolcyclohexane. Suitable dicarboxylic acids include, for example, isophthalic acid, terephthalic acid, phthalic acid, methyl-substituted derivatives of the said acids, tetrahydrophthalic acid, methyl-tetrahydrophthalic acids, for example 4-methyltetrahydrophthalic acid, cyclohexane-dicarboxylic acids, succinic acid, glutaric acid, adipic acid, pimelic acid, suberic acid, azelaic acid, sebacic acid, dodecanedicarboxylic acid, fumaric acid, maleic acid and 4,4'-diphenyldicarboxylic acid etc.. Suitable tricarboxylic acids include, for example, aliphatic tricarboxylic acids, such as 1,2,3-propanetricarboxylic acid, aromatic tricarboxylic acids, such as trimesic acid, trimellitic acid and hemimellitic acid, and cycloaliphatic tricarboxylic acids, such as 6-methylcyclohex-4-ene-1,2,3-tricarboxylic acid. Suitable tetracarboxylic acids include, for example, pyromellitic acid and benzophenone-3,3',4,4'-tetracarboxylic acid. Commercially available polyesters especially are very commonly based on neopentyl glycol and/or trimethylolpropane as the main alcoholic monomer constituent(s) and on adipic acid and/or terephthalic acid and/or isophthalic acid and/or trimellitic acid as the main acidic monomer component(s).

Component (B) constitutes preferably from 0.7 to 2 percent by weight, especially from 0.7 to 1.8 percent by weight, of the composition according to the invention based on the total weight of components (A), (B) and (C). It is furthermore preferred for component (B) to

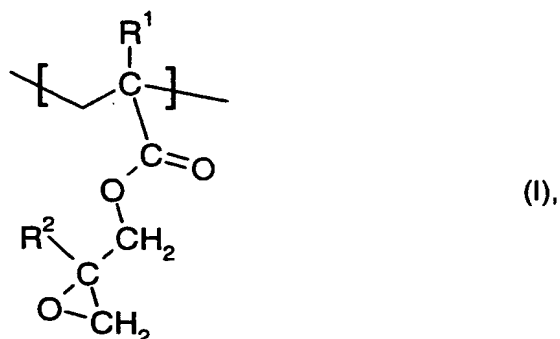
constitute from 5 to 50 percent, especially from 7.5 to 25 percent, of the total weight of the polyglycidyl components (B) and (C).

The polymers and copolymers constituting component (B) of the compositions according to the invention preferably have a molecular weight (number average  $M_n$ ) of from 1000 to 10 000. The polymers and copolymers can be prepared, for example, by a conventional free-radical polymerisation of a monomer selected from glycidyl acrylate, glycidyl methacrylate,  $\beta$ -methylglycidyl acrylate and  $\beta$ -methylglycidyl methacrylate, optionally in the presence of a suitable amount of free-radically polymerisable comonomer(s). The polymerisation can be carried out, for example, by dissolving the monomers in a suitable organic solvent, such as toluene, 1-methoxy-2-propanol, 1-methoxy-2-propyl acetate or methyl isobutyl ketone, or in a mixture of the said solvents, and heating the resulting solution in the presence of a suitable initiator, such as, for example,  $\alpha, \alpha'$ -azoisobutyronitrile or dicumyl peroxide, optionally in the presence of a chain terminator, such as, for example, allyl glycidyl ether. Suitable comonomers include, for example, (meth)acrylic acid esters, such as ethyl acrylate, butyl acrylate, 2-ethyl hexylacrylate, and also, especially,  $C_1$ - $C_4$ alkyl methacrylates, such as methyl methacrylate, ethyl methacrylate and butyl methacrylate, and furthermore, for example, acrylo- and methacrylo-nitriles, (meth)acrylamides and also vinyl compounds, for example aromatic vinyl compounds, especially styrene and styrene derivatives.

It is also possible, however, to glycidylise a poly(meth)acrylic acid polymer or a poly(meth)-acrylic acid copolymer according to one of the conventional methods, for example by reacting the polymer or copolymer with an excess of epichlorohydrin in the presence of a suitable catalyst, after which the resulting polyhalohydrin esters are dehydrochlorinated using a hydrogen-chloride-binding agent.

Component (B) consists preferably of polymers or copolymers each having an epoxy value of at least 5 equivalents per kilogram.

It is more especially preferred for component (B) to be constituted by polymers that consist substantially of identical or different structural repeating units of formula (I):



wherein  $\text{R}^1$  and  $\text{R}^2$  are each independently of the other a hydrogen atom or a methyl group, especially when  $\text{R}^2$  in formula (I) is a hydrogen atom. Finally, the polyglycidyl component (C) constitutes preferably from 0.1 to 38 percent by weight, especially from 5 to 15 percent by weight, of the composition according to the invention based on the total amount of components (A), (B) and (C).

Component (C) consists of one or more polyglycidyl or poly( $\beta$ -methyl)glycidyl compounds each having an epoxy value of at least 3.5 equivalents per kilogram. Those compounds, in contrast to the polyglycidyl compounds constituting component (B) of the compositions according to the invention, are monomeric compounds having a maximum molecular weight of 600 (molecular weight being understood in this case to mean the sum, calculated theoretically for each of the compounds, of the weights of the atoms of the molecule), for example corresponding diglycidyl or triglycidyl compounds that are preferably solid at room temperature, or corresponding polyglycidyl compounds having an even larger number of glycidyl groups per molecule.

Preferably, component (C) of the compositions consists of one or more glycidyl compounds having an epoxy value of at least 4 equivalents, especially at least 5 equivalents, per kilogram.

Examples of glycidyl compounds that are suitable as component (C) of the compositions according to the invention include, *inter alia*, trimellitic acid triglycidyl ester, triglycidyl isocyanurate, hexahydroterephthalic acid diglycidyl ester, especially *trans*-hexahydroterephthalic acid diglycidyl ester, hexahydroisophthalic acid diglycidyl ester, hexahydrotrimellitic acid triglycidyl ester, terephthalic acid diglycidyl ester, isophthalic acid diglycidyl ester and cyclohexanedimethanol diglycidyl ether.

For the composition according to the invention it is furthermore preferred for the epoxy value of components (B) and (C) together likewise to be at least 3.5 equivalents, preferably at least 5 equivalents, per kilogram of the mixture of the two components.

The compositions according to the invention preferably have a slight molar excess of epoxy groups. The molar ratio of glycidyl groups to carboxyl groups in the compositions is thus preferably from 1.3:1 to 1:1, for example approximately from 1.2:1 to 1.1:1.

In order that the curing reaction can proceed sufficiently rapidly, the compositions according to the invention also contain, as component (D), a catalyst for the reaction of epoxy groups with carboxyl groups. Such a catalyst is frequently an organic amine or a derivative of an amine, especially a tertiary amine or a nitrogen-containing heterocyclic compound. Preferred catalysts for the reaction of epoxy groups with carboxyl groups are phenylimidazole, N-benzyl dimethylamine and 1,8-diazabicyclo[5.4.0]-7-undecene, optionally on a silicate support or triphenylphosphine, Actiron® NXJ-60 (2-propylimidazole), Actiron® NXJ-60 P (60 % by weight of 2-propylimidazole on 40 % by weight of solid support), Beschleuniger® DT 3126 ( $[C_{16}H_{33}N(CH_3)_3]^+ Br^-$ ). The catalyst or a catalyst mixture is preferably added in such an amount that the gel time of the mixture at 180°C (determined according to DIN 55990) is approximately from 70 to 400 seconds, preferably from 90 to 300 seconds. Generally, approximately from 0.1 to 10 percent by weight, especially from 0.5 to 5 percent by weight, of catalyst will be required for that purpose. Of course some commercially available polyesters that are used as a constituent of component (A) of the compositions according to the invention will already contain a certain amount of one of the above-mentioned catalysts or of a comparable catalyst, and that amount should be taken into account in the above percentage by weight figure for catalyst; the mentioned preferred gel times can be used to provide an indication of how much catalyst still needs to be added.

In addition to the components already mentioned, the compositions according to the invention may, of course, contain further components, which may vary according to the field of application of the compositions and which will be known to the person skilled in the art in question.

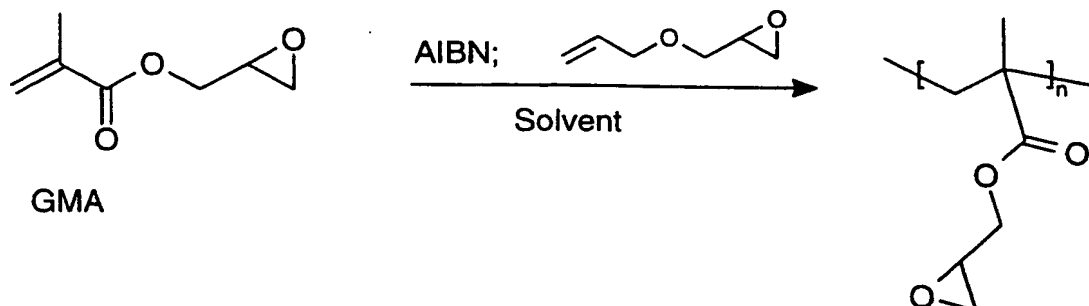
Powder coating compositions based on the compositions according to the invention may, for example, also contain additives customary in the surface-coating industry in the amounts conventionally used therefor, such as, *inter alia*, light stabilizers, curing accelerators, dyes, pigments, for example titanium dioxide pigment, degassing agents, for example benzoin, and also additional flow agents. Suitable flow agents include, for example, polyvinyl acetals, such as polyvinyl butyral, polyethylene glycol, polyvinylpyrrolidone, glycerol and acrylic mixed polymers, such as, for example, those available under the names Modaflow® and Acrylon .

The powder coating compositions according to the invention can be prepared simply by mixing the constituents together, for example in a ball mill. Another, more preferred possibility comprises melting together, blending and homogenising the constituents, preferably using an extrusion machine, such as a Buss co-kneader, and cooling and comminuting the resulting mass. In that procedure, the fact that either immediately after extrusion, or at least after they have been left to stand for a few hours, for example from 24 to 48 hours, the powder coating compositions according to the invention become so hard and brittle that they can readily be ground, has proved especially advantageous. The powder coating mixtures preferably have a particle size in the range from 0.015 to 500 µm, especially from 10 to 75 µm. In some cases it may also be advantageous first of all to prepare a masterbatch from portions of the binder, the epoxy resins and, optionally, further components, the masterbatch then being mixed and homogenised in a second step with the remainder of the binder and the remaining constituents to yield the finished powder coating composition.

After application to the article to be coated, the powder coating compositions are cured at a temperature of at least approximately 100°C, preferably at from 150 to 220°C. Curing generally takes approximately from 5 to 60 minutes. All materials that are stable at the temperatures required for the curing, especially ceramics and metals, are suitable for coating. The substrate may already have one or more base surface-coatings that are compatible with the powder coating composition.

The powder coating compositions exhibit a good flow behaviour combined with good mechanical properties, good weather resistance and good resistance to chemicals.



**Example 1:** Preparation of a glycidyl methacrylate (= GMA) homopolymer

The free-radical polymerisation is carried out using AIBN ( $\alpha, \alpha'$ -azoisobutyronitrile) as initiator. The desired low molecular weight ( $M_w$  or  $M_n$ ) is achieved by selecting the amount of initiator, the amount of chain terminator (allyl glycidyl ether in the present case) and the polymerisation temperature. In the polymerisation procedure used in this instance, the major portion of the monomer mixture (90 %), the full amount of initiator and the major portion of the solvent are metered within a period of two hours into an initial charge in the reactor, the initial charge consisting of the remainder of the monomer mixture (10 %) and the remainder of the solvent. This allows good control of the polymerisation exotherm and helps to achieve a molecular weight that is reproducible. Many variants of the reaction procedure are, of course, possible; the person skilled in the art will find that it is simple to determine suitable conditions.

The polymerisation apparatus consists of a heatable 3000 ml double-walled jacket reactor with stirrer, reflux condenser, thermometer, nitrogen purging means, feed receptacle and feed pump ("Masterflex" peristaltic pump). A monomer mixture consisting of 1300.50 g of methacrylic acid glycidyl ester and 144.50 g of allyl glycidyl ether is prepared. The reactor is charged with 144.50 g of the monomer mixture and 867.00 g of methoxypropyl acetate (MPA, solvent). The feed receptacle is filled with the remainder of the monomer mixture (1300.50 g), 96.50 g of MPA and 72.25 g of AIBN. The AIBN should be homogeneously dissolved. The entire apparatus (including the feed receptacle) is rendered inert with nitrogen, the reactor is heated to an internal temperature of 100°C (jacket temperature of 105°C) and the feed is then started. The rate of feed is so selected that the feed takes about 2 hours. The stirring speed is 100 revs/min. When the feed is complete, polymerisation is continued for a further 2 hours at 100°C under nitrogen. The viscous solution is precipitated in hexane and the solvent is decanted off. The greasy residue is dissolved in acetone and precipitated from water. The precipitation residue is reprecipitated once more from

acetone/water. The solid polymer is filtered off and dried *in vacuo*. 1200.00 g of colourless polymer in powder form, having the following analytical data, remain:

$T_g$ , measured by DSC : 31°C

GPC (polystyrene calibration):  $M_w = 7147$ ;  $M_n = 2986$

Epoxy value, titrimetric: 6.44 equivalents/kg

**Example 2:** Preparation of a further GMA homopolymer

The following are polymerised in accordance with the procedure indicated in Example 1:

Monomer mixture: 144.50 g of glycidyl methacrylate + 25.50 g of allyl glycidyl ether

Initial reactor charge: 17.00 g of monomer mixture + 102.00 g of MPA

Feed: 153.00 g of monomer mixture + 11.30 g of MPA + 8.50 g of AIBN

158.30 g of colourless polymer in powder form, having the following analytical data, are obtained:

$T_g$ : 42°C

GPC (polystyrene calibration):  $M_w = 6099$ ;  $M_n = 1304$

Epoxy value, titrimetric: 6.39 equivalents/kg

**Example 3:** Preparation of a GMA copolymer (Rt 2549/1)

The following are polymerised in accordance with the procedure indicated in Example 1:

Monomer mixture: 25.50 g of butyl methacrylate + 127.50 g of glycidyl methacrylate + 17.00 g of allyl glycidyl ether

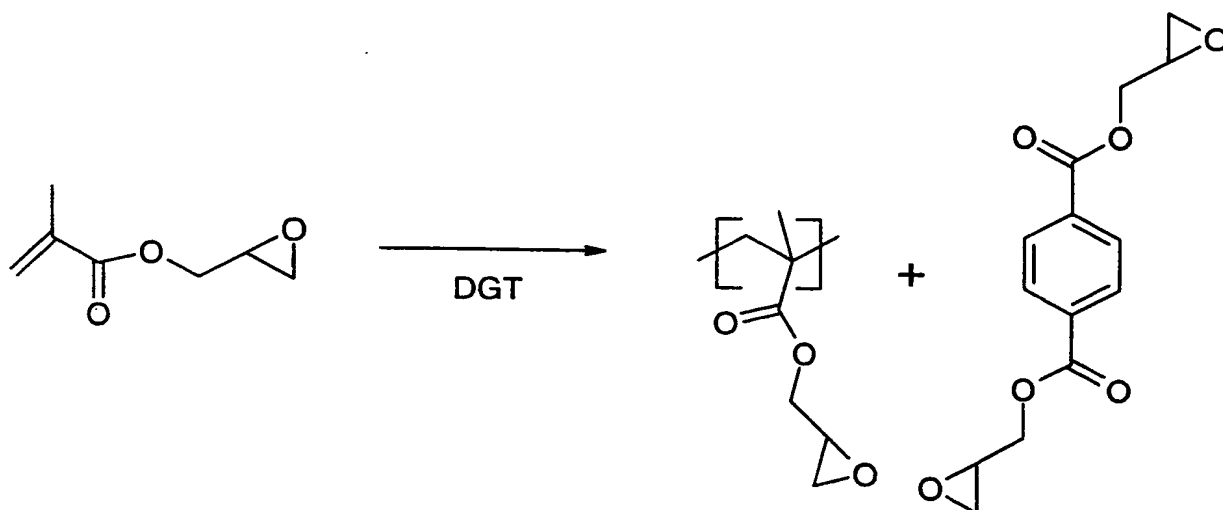
Initial reactor charge: 17.00 g of monomer mixture and 102.00 g of MPA

Feed: 153.00 g of monomer mixture + 11.30 g of MPA + 8.50 g of AIBN

The isolation of the solid polymer is slightly modified: the polymer solution is concentrated to dryness using a rotary evaporator, the residue is dissolved in acetone and then precipitated from ice-water. 157.00 g of colourless polymer in powder form, having the following analytical data, are obtained:

GPC (polystyrene calibration):  $M_w = 7182$ ;  $M_n = 1926$

Epoxy value, titrimetric: 5.47 equivalents/kg

**Example 4:** Free-radical polymerisation of GMA in diglycidyl terephthalate (DGT)

200 g of diglycidyl terephthalate (DGT) are introduced into a 1 litre flat ground flask. 40 g of glycidyl methacrylate (GMA) and 4 g of 1,1-bis(tert-butylperoxy)-3,3,5-trimethylcyclohexane (50% solution = Trigonox 29, C50 from AKZO) are introduced into a 250 ml taper-necked flask. The two flasks are connected to each other. The flat ground flask is heated by means of an oil bath until the DGT has melted. When all of the DGT has melted, the 1 litre flat ground flask, together with the 250 ml supply flask connected to it, is evacuated and filled with nitrogen a total of five times. The mixture of GMA and 1,1-bis(tert-butylperoxy)-3,3,5-trimethylcyclohexane is then fed from the 250 ml supply flask into the molten DGT within a period of 20 minutes, with stirring, and the batch is left to react for 3.5 hours with further stirring. On subsequent cooling, the liquid mass solidifies.

Yield: 236 g (98%)

GPC (polystyrene calibration):  $M_w = 15\,700$ ;  $M_n = 8921$

Epoxy value, titrimetric: 6.86 equivalents/kg

**Example 5:**

Using an extruder (laboratory extruder from PRISM, The Old Stables, England), the powder coating compositions indicated in the following Tables 1a and 1b are homogenised at a temperature of from 60 to 80°C. The total amount of powder coating composition in each case is approximately from 100 to 200 grams. The cooled extrudates are ground to give the finished powder coating composition having a particle size of approximately 40 µm.

**Table 1a:** Powder coating composition formulations A to C according to the invention and comparison coating compositions E to G

Formulation/ amounts [% by wt.]	Invention			Comparison		
	A	B	C	E	F	G
Uralac P 3485 <sup>1)</sup>	58.98	59.96	90.77	59.08	59.81	59.95
DGT	4.69	3.97	6.01	4.89	---	---
GMA polymer of Ex. 1	---	1.03	---	---	5.16	---
GMA polymer of Ex. 2	---	---	1.52	---	---	5.02
GMA polymer (6.7 eq/kg)	0.80					
DT 3126-1 <sup>2)</sup>	0.50	---	---	1.00	---	---
Benzoin	0.20	0.20	0.20	0.20	0.20	0.20
Acrylon <sup>3)</sup>	1.50	1.50	1.50	1.50	1.50	1.50
TiO <sub>2</sub> pigment	33.33	33.33	---	33.33	33.33	33.33

<sup>1)</sup> Polyester based on terephthalic acid, isophthalic acid and neopentyl glycol having an acid number of 28 and a glass transition temperature T<sub>g</sub> of 71°C;

<sup>2)</sup> Alkylammonium salt in polyester;

<sup>3)</sup> Acrylic mixed polymer as flow agent.

**Table 1b:** Powder coating composition formulations H to K and P according to the invention

Formulation [% by wt.]	Invention				
	H	I	J	K	P
Polyester <sup>4)</sup>	<i>Uralac P-3485</i> 58.71	<i>Crylcoat 801</i> 57.61	<i>Crylcoat D-6210</i> 59.66	<i>Alftalat 9952</i> 58.90	<i>Uralac P-3485</i> 59.09
DGT/GMA mixed polymer	5.76 <sup>5)</sup>	6.86 <sup>5)</sup>	4.81 <sup>5)</sup>	5.57 <sup>5)</sup>	5.38 <sup>6)</sup>
Benzoin	0.20	0.20	0.20	0.20	0.50
Acrylon	1.50	1.50	1.50	1.50	0.20
XB 3126	0.50	0.50	0.50	0.50	1.50
TiO <sub>2</sub> pigment	33.33	33.33	33.33	33.33	33.33

<sup>4)</sup> Polyester based on terephthalic acid, isophthalic acid and neopentyl glycol having an acid number and a glass transition temperature according to the following Table:

Polyester	<i>Crylcoat 801</i>	<i>Crylcoat D-6210</i>	<i>Alftalat 9952</i>
Acid number	34	23	27
T <sub>g</sub> (°C)	73	72	64

\*First DSC run.

<sup>5)</sup> Mixture of approximately 86 % by weight DGT and 14 % by weight GMA homopolymer having an epoxy value of 6.37 equivalents per kilogram of the mixture.

<sup>6)</sup> Mixture of DGT and GMA homopolymer according to Example 4.

Using an electrostatic spray pistol, the powder coating compositions are applied to Q panels as substrate. The coated panels are then placed in an oven in order to melt and fully cure the powder coating composition. The gel time, the curing temperature and the curing time,

and also the thickness of the resulting powder resin coating, are indicated in the following Tables 2a and 2b together with properties of the resulting coatings that are important from the standpoint of surface-coating technology.

**Table 2a:** Properties, important from the standpoint of surface-coating technology, of the coatings obtained using compositions A, B, C and E, F, G

	Invention			Comparison		
	A	B	C	E	F	G
Gel time <sup>8)</sup> at 180°C [s]	220	170	90	205	25	20
Curing conditions	15 min./180°C	15 min./180°C	15 min./180°C	15 min./180°C	15 min./180°C	15 min./180°C
Layer thickness [µm]	60	53	59	60	59	60
60° gloss	94	96	124	87	18	21
20° gloss	85	77	117	95	60	65
Yellowness value Y <sub>i</sub> <sup>7)</sup>	0.2	-0.8	---	-1.2	-1.1	-0.8
Flow <sup>8)</sup> [rating]	10	10	12	12	orange-peel	orange-peel
Impact deformation, reverse <sup>9)</sup> [kg cm]	160	160	160	160	<5	<5
Impact deformation, front [kg cm]	160	160	140	160	80	80
Acetone test, <sup>10)</sup> 1 min. [rating]	3	3	3	5 not cured	3	3
Appearance	satisfactory	satisfactory	satisfactory	satisfactory	mat	mat

<sup>8)</sup> Empirical scale from 0 (very good) to 18 (orange-peel)

<sup>9)</sup> The impact deformation is determined by dropping onto the coated face a punch weighing 2 kg, having a 20 mm diameter ball on its underside, with the underside leading, from a specific height from behind (reverse side) or from the front. The value indicated is the product of the weight of the punch in kg and the test height in cm at which there is still no detectable damage to the coating.

<sup>10)</sup> According to DIN 53320. The specimen is kept in acetone for 1 minute. The result is evaluated in accordance with the following scale of five ratings: 0 = unchanged; 1 = resistant, cannot be scratched with a finger nail; 2 = difficult to scratch, may stain cottonwool pad; 3 = softened, easily scratchable; 4 = beginning to separate or dissolve; 5 = complete dissolution.

**Table 2b:** Surface-coating technology properties of the coatings using compositions H to K, P

	Invention				
	H	I	J	K	P
Gel time at 180°C [s]	225	275	180	170	260
Curing conditions	15 min. / 200°C	15 min. / 200°C	15 min. / 200°C	15 min. / 200°C	15 min. / 180°C
Layer thickness [μm]	60	55	50	47	46
60° gloss	89	95	94	96	95
20° gloss	76	88	84	83	85
Yellowness value Yi	-0.4	0.0	-1.0	-1.8	-1.5
Flow [rating]	8	8	10	10	10
Impact deformation, reverse [kg cm]	>160	120	>160	>160	>160
Impact deformation, direct [kg cm]	>160	>160	>160	>160	>160
Acetone test, 1 min [rating]	3	3	3	3	3
Appearance	satisfactory	satisfactory	satisfactory	satisfactory	satisfactory